ABG
Environmental Geosynthetics

Guide to Green Retaining Walls

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1. ABG and Green Retaining Walls

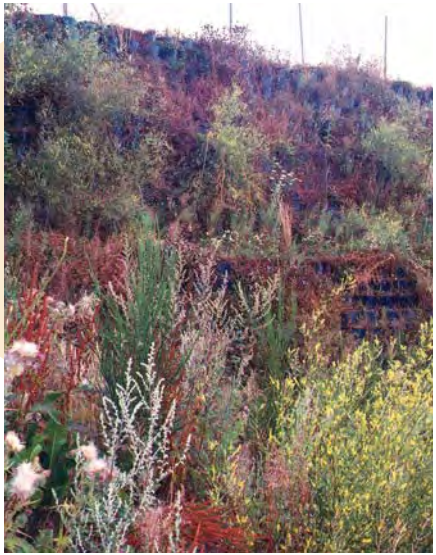
ABG Ltd are a UK based manufacturer and supplier of specialist geosynthetic materials. We offer an extensive range of materials, including retaining wall systems, geocomposite drainage products, geotextiles and several specialist SUDS related systems.

We pride ourselves on being a pioneer and innovator of environmental solutions. This includes being a contributor to the WRAP report on 'Sustainable Geosystems in Civil Engineering Applications' which focuses on the use of sustainable products.

We first became involved in retaining wall systems and reinforced earth solutions 20 years ago when we developed and launched our own range of ground engineering products. These products include a cellular retaining wall system known as Webwall. The product was developed as a sustainable, green wall solution manufactured using a mixture of prime and recycled HDPE.

The aim of this guide is to demonstrate the range of retaining walls systems available, with specific focus on green retaining walls and the added benefits that come with using such a system.

The term 'Green retaining wall' not only refers to the finished appearance of the wall i.e through planting of the front face, but also its 'green credentials' which we will explore throughout the course of this guide.



2. Introduction to Retaining Walls

Retaining walls have been in use for thousands of years:

- The Romans used retaining walls to aid in the construction of their famous roads.
- Many of the castles in Europe incorporated retaining walls into their design.
- Hillside rice paddies in Asia have depended on retaining walls for hundreds of years.

Developments of all types now use retaining walls to maximise the usable area of the chosen site. Often the land can vary from a gentle slope to a steep hill and therefore a method of engineering is required to increase the usable space. One way of doing this is to utilize retaining walls, making them an integral part of any design.

There are several types of retaining wall structure that can be implemented to create the extra space required. These structures have several different types but can generally be classified in two ways:

Traditional retaining wall *systems: these include gabions baskets, crib walls, concrete walls & steel piled walls.*

Green retaining wall *systems consisting of a cellular structure, such as ABG Webwall.*

3. Terminology - Cut & Fill

Two of the most common terms associated with retaining walls are 'Cut' and 'Fill'.

A '**Cut**' wall is as simple as it sounds. This is when you cut into an existing embankment or hillside to gain additional space. The retaining wall then has to retain the material behind the cut which can vary in density, structure, hydrology, surcharges and angles of slip. It is important to note that this method of construction can create a large quantity of waste material. This may need to be disposed of which has cost implications and a large impact on site waste management plans.

A '**Fill**' wall is built in front of the existing embankment or hillside and material is then compacted behind the wall to create additional space. A fill wall can help dramatically with the use of site won material which would otherwise have to be taken to landfill.

The need for a cut or fill wall will be determined by the topography of the site, desired finished level and position of the infrastructure. Often a site will require both cut and fill walls.

4. Terminology - cont.

Gravity Retaining Wall
A gravity retaining wall is usually a low height (less than 2m) wall which depends on its own weight to hold back the material behind and any surcharges above.

Reinforced Soil Retained Wall
A reinforced soil retained wall is for walls greater than 2m in height. Typically the reinforcement comes in the form of a geogrid such as ABG's Trigrid. This product is installed at each level and uses friction and interlock to tie the wall back in to the ground behind (depth equal to the height of the wall).

Other commonly used terms:

Retained Height: *the height of the material to be retained.*

Foundation or Foot: *the base on which the wall is constructed on.*

Overturning moment: *the effect of the soil pressure tending to rotate the wall forward.*

Parapet: *extension of the wall above retained soil level - perhaps a safety fence.*

Parapet: *the height the wall extends above the retained height.*

Surcharges: *where other forces are put on the wall which can include trafficking loads.*

Hydrostatic Pressure: *occurs when water is allowed to build up in the fill behind the wall.*

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5. Traditional Solutions - Gabions

Gabions are one of the most widely used forms of gravity retaining walls. Commonly used for gardens, commercial embankments and at the side of highways. Gabion walls consist of a series of wire mesh baskets, which are either welded or woven, and then hand filled with imported stone.

Woven gabions

Woven gabions are formed by weaving adjacent strands of wire by twisting them through one and a half turns at intervals, forming a hexagonal shaped mesh. The ends of the mesh wires are wrapped around a heavier transverse edge wire to form the panels. The tensile strength of the mesh in the direction of the weave is greater than across the weave.

Welded gabions

Welded gabions are manufactured from dimensional stable panels of mesh, that are formed by welding transverse and longitudinal wires at each and every intersection to form a grid then wires are interwoven at the corners to hold the basket together. Trapezoidal gabions allow different aesthetics and slight flexibility in design.

Advantages:

- Accommodates differential settlement
- Simple construction
- Free draining

Disadvantages:

- Stone fill usually imported
- Time consuming to install
- Harsh appearance
- High embedded carbon
- Increased number of vehicle movements required for import of stone fill

6. Traditional Solutions - Crib wall

Crib walls are constructed by interlocking individual boxes made from timber, pre-cast concrete or metal members to create gravity retaining walls. The boxes are filled with crushed stone or other coarse granular materials to create a free-draining structure. The units are spaced so that the fill material contained within the crib, is not affected by climatic change and acts in conjunction with the crib work to support the retained earth.

There are two main types of crib wall:

Timber

Timber crib walls are commonly built from logs or treated wood and so the required design life must be taken into account.

Precast concrete

Precast concrete crib units are a more permanent option and are constructed in the same way as the wooden units. The infill is built in as each course is assembled and therefore the crib wall is essentially a fully operating structure at each stage of its construction. The use of mechanical plant is recommended to speed up the construction.

Advantages:

- Durable provided timber cribs are treated
- Free draining structure
- Aesthetically pleasing

Disadvantages:

- Increased construction time and therefore labour costs
- Vegetation can take a long time to establish within cribs
- High embedded carbon
- Increased number of vehicle movements required for import of stone fill

7. Traditional Solutions - Cantilever

Cantilever retaining walls are constructed of concrete. They consist of a relatively thin stem and a ***base slab*** or ***footing***. The base is also divided into two parts, the ***heel*** and ***toe***. The heel is the part of the base under the backfill. The toe is the other part of the base.

The cantilever wall relies on the stiffness of the stem of the wall to hold back soil pressure; the buried base prevents the stem from moving. It is the task of the designer to ensure that the base is large enough to restrain the stem, and that the stem is strong enough to resist the soil.

For relatively small heights of wall the use of precast concrete wall sections is common; for larger heights, for more difficult soils, for aesthetic reasons and in various other particular situations, in-situ concrete is usually preferred. In particular, precast walls usually require good foundation soils and are best suited to "fill" situations.

Advantages:

- Units can be re-used
- Quick to install

Disadvantages:

- Plant intensive installation/Crane required
- Appearance - plain concrete face
- Non draining, additional drainage required
- Graffiti prone

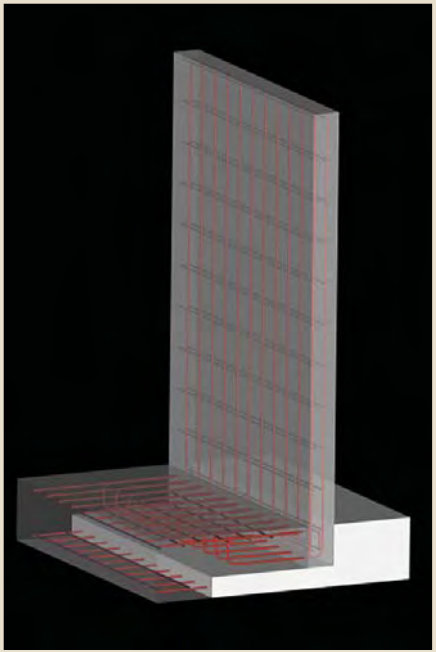
8. Traditional Solutions - Embedded Cantilever

Instead of the base or footing of other cantilever walls, embedded cantilever walls rely on an extended "stem" buried in the ground to restrain the wall in place. The depth to which the wall must be embedded depends on the ground conditions and on any loads that may be applied to the soil retained by the wall, such as further building or traffic. In unfavourable conditions the depth of embedment can be substantially greater than the height of soil retained.

The advantage of embedded retaining walls is that they are built "within the ground". T-shaped and L-shaped cantilever walls can require substantial excavation and associated working space to allow the footing to be constructed. Conversely, embedded walls can require large machinery to construct them, with correspondingly high mobilisation costs.

There are essentially three materials used for construction of embedded cantilever walls: timber, reinforced concrete and steel. Timber is neither as stron g nor as durable as reinforced concrete or steel. However, satisfactory walls can be constructed to heights of around 3.0m with suitable timber.

Embedded cantilever walls are essentially only suitable for "cut" situations.



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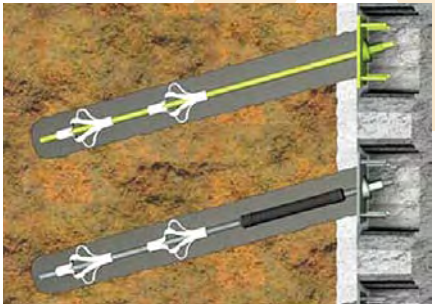
9. Other Traditional Methods

Soil Nailing

Soil nailing is a technique in which soil slopes, excavations or retaining walls are reinforced by the insertion of relatively slender elements - normally steel reinforcing bars. The bars are usually installed into a pre-drilled hole and then grouted into place or drilled and grouted simultaneously. They are usually installed un-tensioned at a slight downward inclination. A rigid or flexible facing (often pneumatically applied concrete otherwise known as shotcrete) or isolated soil nail heads may be used at the surface.



Soil Nailing can only be used in certain situations dependent on several factors including ground conditions and topography.

Modular Block

Individual, usually identical, precast concrete units either interlock, offset stack, or are placed structurally independent of each other and anchored into the backfill. The components of a complete system can include foundation soil; levelling pad; precast concrete units of high-strength concrete; shear pins if units don't interlock; multiple-depth walls or additional soil reinforcement such as ABG Trigrid, welded wire fabric, or soil anchors if the wall is over a certain height; retained soil; and drainage geocomposite/medium.

Being gravity structures, these systems rely on their own weight and coherent mass to resist overturn and sliding forces.

Piled Walls

Reinforced concrete walls are typically secant and or contiguous bored piles, which are installed by a large crane-mounted piling machine. By far the most common form of steel is sheet piles which are generally driven into the ground by a crane mounted hammer.

10. Green Retaining Wall Solutions

The most commonly used green retaining walls come in the form of a cellular confinement system, such as ABG Webwall. This type of retaining wall system consists of a honeycomb structure. The cell structure strengthens structural fill, via the hoop strength of the cell walls, the passive resistance of adjacent cells, and the frictional interaction between infill and cell walls. These mechanisms create a bridging structure with high flexural strength and stiffness; thereby improving the long term load deformation performance of common granular fill materials.

Unlike traditional systems one of the biggest advantages is that geocellular walls require no imported material as they can be constructed using site won material. This can help dramatically with site waste management plans, the reduction of carbon emissions, and cost associated with the project.

Although they are manufactured from a variety of materials, a HDPE composition (Webwall) is preferable as it offers additional rigidity and strength which is important particularly during the installation phase.

Once constructed the front cells of the green wall should be planted to create an aesthetically pleasing finish and increase the sites biodiversity.

Please note: *Cellular confinement systems can also be used in single layers to reinforce the surface of a slope or in basal applications such as access roads to strengthen the fill material.*

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11. Green Walls Vs Traditional Walls

Why chose a Green Retaining Wall over a Traditional Retaining Wall?

Traditional retaining walls are common place throughout the UK and can be seen on most developments in one form or another. Although the green retaining wall systems are far less common this is beginning to change. There are a number of key reasons we are seeing this change.

Aesthetically pleasing finish.

A green wall has a planted finish meaning that over time the whole face of the wall will be covered with vegetation. This enables them to blend in more with the natural environment. In some cases they add much needed greenery to developments that predominantly contain hard landscaped finishes. This is normally preferable for developers who want the presence of green areas without the sacrifice of valuable space. This too can help in attaining valuable BREEAM and CEEQUAL points in instances where site ecology and biodiversity need to be maintained or increased.

Reduction in surface water run-off

A planted green retaining wall will not only filter pollutants but will also reduce surface water run-off. The extra vegetation within the green wall will absorb the vast majority of rainfall that falls on it during heavy storms. In contrast a solid concrete structure will absorb little, creating additional pressure on the surrounding sewer systems.

Lower Cost

Typically green retaining wall systems have a lower initial cost. They are less labour intensive to install and require no imported fill. Examples of the savings that can be made are shown below.

Project Example: Traditional Vs Green

Factors considered include: Transport, Waste & Cost Factors

Based upon the following assumptions:

- Retaining wall with 3m retained height, 50m in length
- Ground consists of firm silty sand (too dirty for use as engineered fill without processing)
- Ground profile assumed to need both cut and fill which are balanced
- Lorry load with 20 tonne capacity / Soil at 1.6 tonnes/m^3

Factors to Consider	Retaining Wall Type Gabion (Traditional)	Webwall (Green)
Total material excavation	775m^3	775m^3
Total retained for use in construction of retaining wall	500m^3	758m^3
Excavated material now waste	275m^3	17m^3
Imported fill required (stone etc)	275m^3	0m^3
Lorry movements (inc. delivery to site & removal)	45	<5
Approximate cost* (inc material, fill & disposal)	£37,000	£25,000

** Costs obtained from Spon's price guide books for Civil Works, Landscaping & External Works 2010*

12. Design Considerations - General

Drainage / Hydrostatic Pressure

Most retaining walls that fail, fail because of hydrostatic pressure against the wall caused by water or soil-moisture build up behind the wall. All walls should provide for the back-of-wall water to freely drain down and away from the wall. This can be accomplished using a drainage geocomposite such as ABG Fildrain.

Foundations

A wall is only as good as its foundation, and all retaining walls should be built on structurally sound, compacted foundation sub-base material. Levelled and compacted earth or gravel fill are acceptable. The foundation material should extend below the frost susceptible depth.

Batter

Walls are more stable and structurally secure if they slope back or "***lay back***" into the retained slope. This amount of variance from true vertical is called "***batter***". How far the wall can be '***battered***' back should be considered at the outset. This is largely dependent upon the 'workable' space available on site.

Cost/Ease & Speed of Construction

In some instances the initial cost of the materials can be a key factor in determining which system to use. It is vital to consider the true cost and evaluate other costs incurred through removal of spoil from site to landfill, import of material and speed of construction.

Materials

When choosing materials, select the type that is best suited for the desired result.

13. Design Considerations - Environmental/Waste Issues

CO_2

There are several environmental issues with building walls ranging from site contamination to the disruption of site biodiversity. One key factor becoming ever more prevalent in the face of climate change is that the waste created and carbon emitted in the construction of projects. This is being monitored and controlled with site waste management plans for projects over £300,000 in value: although some construction companies now insist on a plan for every site. Not only does the plan control the amount of waste and carbon emitted but can assist with the sites profitability of the project.

The amount of embedded carbon in materials used can in some cases be extremely high. Some of the more traditional retaining wall structures suffer in this respect. Gabion walls for example tend to use large quantities of quarried stone, whilst steel structures emit vast amounts of carbon within the production process.

Aside from the production process it is also important to look at the transportation of materials. When using systems which either require large amounts of waste material removing to landfill or imported material to site, the amount of vehicle movements and pollutants created are also taken into account in the site waste management plans.

Site Waste

One of the drivers of looking at the amount of waste generated for landfill is WRAP. WRAP made a commitment to half the amount of construction waste sent to landfill by 2012. This is commonly known as the 'Waste 2 Landfill commitment (W2L)'. To date companies who have committed to achieving this goal include ASDA, Sainsburys, Land Securities, Lend Lease, Bovis, and Balfour Beatty to name but a few.

The use of green retaining structures such as Webwall is one way to help attain this commitment by enabling more site won material to be constructively used on site.

Mendip Hills

Mendip Valleys

14. Webwall

We have looked briefly at the topic of green retaining walls and how they compare with more traditional systems. We would now like to focus upon one specific example of a green retaining wall system, Webwall, in order to evaluate its merits in more detail.

Applications

Webwall can be used in the construction of both gravity and reinforced retaining structures, visual bunds and embankment stabilisation,

Construction

Webwall is constructed from high density polyethylene strips securely interlocked at the joints with nylon thread to create a honeycomb structure. This structure allows for flexible design meaning the wall can be laid to allow for changes in height and deviation along the length of the wall. Webwall is supplied in different colours and size to suit the project.

Life expectancy

Webwall has life expectancy in excess of 50 years once covered with vegetation. The product is also manufactured from high density polyethylene designed with an additive package to protect against UV degradation.

Appearance

Although the façade can be varied in colour, the intention is that the front cells are planted with vegetation to achieve a natural appearance over time. If required Webwall can be hard faced to give a traditional appearance with either bricks, blocks or panels.

Recycled Content

Webwall contains a minimum of 60% recycled polymer.

Sizes

Webwall Panel Type	A	B	C
Panel Width (m)	1	1.5	2
Panel Length (m)	4	4	4
Panel height (mm)	250	250	250
Cell diameter (mm)	500	500	500
Panel height (mm)	500	500	500
Cell diameter (mm)	500	500	500

***Please note**: Panel sizes can be adapted to suit an individual project.*

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15. Webwall - Ancillaries

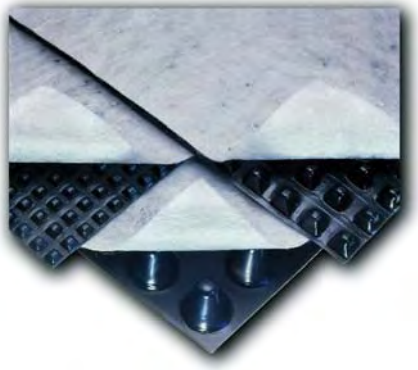
Drainage - ABG Fildrain

All retaining walls require drainage to alleviate the hydrostatic pressure Traditional methods used consist of a 500mm deep layer of drainage stone. A more cost effective solution is to install a layer of ABG Fildrain.

Although modular retaining wall systems like Webwall are relatively free draining; a layer of drainage material is still advised behind the wall itself. Fildrain is a drainage geocomposite which is used in strip form as opposed to a continuous layer. It consists of a dimpled recycled plastic core with an integral filter fleece wrap. A 6mm thick Fildrain installed at metre centres would offer a vastly improved performance over the drainage stone as it creates a clear void space to channel the water away from behind the wall.

Other advantages:

- Supplied in rolls - easy handling/storage
- Simple/quick to install
- Cost effective in comparison with stone



16. Webwall - Ancillaries cont.

Geogrid Reinforcement - ABG TRIGRID® EX

For retaining structures over 2m in height a more economical solution can be achieved by using a reinforcement layer within the retained soil.

We recommend ABG TRIGRID® EX for retaining wall applications. Trigrid is an innovative high performance Geogrid. It combines fibre-reinforced polymer strips within a woven structure. Its junctions are high-strength welded which helps create an interlocking structure from a powerful combination of hybrid materials.

TRIGRID® EX is produced from high strength polyester yarns, which have excellent durability and creep behaviour in civil engineering applications. In contrast traditional polypropylene geogrids are characteristically affected by creep to a much greater extent.

Please note: the grade of reinforcement used varies from project to project. Please consult ABG at the design stage for advice.

***Additional ancillaries**: fixing pins are also required to hold the Webwall cells open prior to backfill - typically 19 per webwall panel. Pin size depends upon the depth of the Webwall panel.*

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17. Webwall - Vegetation & Planting

Planting the front facing panels of the Webwall is extremely important not only from an aesthetics perspective but also to enhance the products long term durability through protection from UV. ABG also add a UV inhibitor during the manufacturing of the front facing panels. This provides additional protection.

The type of planting varies dependent upon a number of factors. These include the following:

- Soil condition of the infill
- Desired appearance
- Location & climate
- Orientation
- Height & length of the green retaining wall
- Budget

Planting of the front face of the Webwall can be relatively inexpensive. Examples of plants typically used include:

Shrubs/Trailers:

Berberis darwinii, Cotoneaster horizontalis, Hedera variegate, Lonicera nitida "Baggasens Gold" and Vinca major 'Variegata.

Herbaceous plants:

Ajuga reptans (and its varieties), Bergenia cordifolia, Euphorbia amygdaloides , Lamium maculatum 'Beacon Silver', Alchemilla mollis

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18. Webwall - Installation

First set out the line of the wall and excavate a firm footing A concrete foundation is not required as Webwall is designed to be a flexible system. If the ground is poor or saturated then an additional amount can be excavated and replaced with good quality crushed stone. Note: For high walls a good quality foundation is essential.

Site prior to construction of Webwall

The first Webwall panel is positioned (unexpanded) to the line of the front face, and a single pin is hammered down into the first cell to hold it in place.

The Webwall panel is stretched to the back of the wall, keeping it perpendicular to the front face, and a pin hammered down through the rear cell to hold it in place. Continue to hammer pins into each cell along the face and as many of the cells along the back as necessary to hold the web mattress into shape. All pins should be installed min. 30mm below the level of the web and should not be removed after backfilling.

The Webwall panels are laid the length of the wall, if required cutting the last panel down to length using a disc saw. Alternatively, ABG can manufacture the length of the panels to suit the site.

19. Webwall - Installation cont.

The front Webwall cells are filled with the site material, ensuring any large or sharp stones are removed. These cells can then be shaped to enhance appearance prior to backfill of the remaining cells. Once all Webwall cells have been filled the material should be well compacted prior to installation of the next layer.

This process is then repeated with each subsequent layer having a small setback to create the pockets for planting and repeated to the full height of the wall. Fence posts can be added into the top course if needed.

Where the wall exceeds 2m retained height install a layer of ABG TRIGRID® EX between each tier. Depth should be equal to height of the wall.

20. Webwall - Examples

Allotment, Nottingham

Reservoir, Holmfirth

Bypass, Dudley

Notes

Allotment:
top image - day of installation
bottom image - 3 months later

Reservoir:
top image - during installation
bottom image - 3 weeks later

Bypass:
left hand image - day of completion
right hand image - 6 months later

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21. Summary

In summary there are a wide variety of retaining walls systems available ranging from the more traditional to systems with a 'greener' approach. The choice is of course very much dependent upon a number of factors, including site conditions, workable space and the desired end result to name but a few.

Next time you are looking at a retaining wall on a particular project, whether it be at initial design or construction stage, contact ABG. With over 20 years of experience in green retaining wall systems we can offer advice, structural calculations and/or even a full design.

The overall benefits of ABG's green retaining wall system, Webwall, are summarised below.

Client:

- ✓ Cost effective solution
- ✓ Aesthetically pleasing planted finish
- ✓ Steep batter keeping land lost to a minimum

Architect/Engineer:

- ✓ ABG carry out the necessary structural calculations
- ✓ ABG produce a design free of charge
- ✓ Enhanced biodiversity & BREEAM points.

Contractor:

- ✓ Quick & simple to install - ABG installation service also available where required
- ✓ Little storage space required for materials
- ✓ Reduction in site waste material

Like ABG Webwall make sure your choice of retaining wall ticks all of the boxes.

ABG

Environmental Geosynthetics

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Working in partnership with;

VitalEarth

GROUNDWORK SHEFFIELD

ISOQAR QUALITY ASSURED FIRM ISO 9001 — UKAS QUALITY MANAGEMENT 026 — Certificate number 570

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